Entire Global Space 3D Grids and Application for Low Altitude Airspace Management

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I. Entire Global Space 3D Grids
Entire global space 3D grids are new types of space 3D grids for human activities covering the whole earth space, including satellite space, aviation space, meteorological space, ground, water surface, underground and underwater space. This subdivision grids cover the complete Earth space without leaks or overlaps. Meanwhile, different level grids form a recursive hierarchical tiling structure.
Surface Division of the Earth based on Latitude-longitude Grid:
The origin of this grid system is the intersection of the earth reference ellipsoid, the original meridian and the equator.

To perform recursive subdivision and to form grid cells of whole degree, whole minute and whole second, the spatial subdivision domain is extended to an integer power of 2 as needed. Specifically, the subdivision domain extend three times on the 0th, 9th, and 15th layers, corresponding to the initial space, $1^\circ$, and $1'$.
Extension of Elevation Subdivision:
The third dimension is divided by geodetic height. Our reference ellipsoid can be WGS84 or CSCS2000. The series of height domain subdivision is consistent with the series of earth reference ellipsoid subdivision. For arbitrary subdivision number $m$, the height domain is divided into $2^m$ layers. The height of each grid at the same level should be equal, and should be consistent with the latitude of the equator on the corresponding level.
Theoretical Basis: Geo-coding Rules

Earth Subdivision refers to the multi-level division of the earth’s space to form a continuous three-dimensional grid. Each grid can be given a unique computable code, which can be used as the location identification of the earth’s space area. All information or data on the earth can fall in one or more grids, so we can identify, express, organize and calculate the real earth’s space. This geo-spatial grid coding rules could be recognized as a kind of discrete coding added to the existing longitude and latitude coding.
The earth subdivision model covers the whole Earth Moon three-dimensional space. This model divides the whole earth space into hundreds of millions of centimeter models. In particular, the model adopts the elevation non-equidistant elevation division to solve the "flattening" effect of the grid body in the process of extending the three-dimensional grid from the surface to the elevation dimension, finally achieves the consistent change of the plane particle size and the elevation particle size.
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<th>Type</th>
<th>Standard</th>
<th>Process</th>
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<tr>
<td>GIS</td>
<td>Geographic position grid encoding rules</td>
<td>Will be published in 2020.</td>
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<tr>
<td>UAV</td>
<td>UAV 3D space location identification</td>
<td>Project approval</td>
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<tr>
<td>China High-resolution Earth Observation System</td>
<td>GFB30201-2018《Reference frame for organizing CHEOS satellite remote sensing information 》</td>
<td>Published in April of 2018.</td>
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<tr>
<td>Public security</td>
<td>《Combination of address elements and coding rules of police geographic information standard》</td>
<td>Approval stage</td>
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<td>Housing construction</td>
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<td>Fire protection</td>
<td>《Beidou grid coding standard for fire fighting facilities》</td>
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Typical Application Scenarios
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Top Research Funds Supported by China

National Key Research and Development Program: Global Location Framework and Coding System, 2018.05~2022.04, US$828,000

On the basis of the existing longitude and latitude system and the new achievements of OGC and other important international and domestic grid generation, this program puts forward a location opening framework in line with China’s developments, establishes a unified coding model of longitude and latitude point location and grid area location, constructs a new location service technology, finally provides technical support for the location identification of national global strategy, land and other important departments.

Three Key Scientific Issues:

- Unified reference framework for global location
- Global location integration coding method
- Global location integration data model
Project Research Highlight

Multiple Earth Subdivision Grids
(infinite numbers)

8 Types of Lattice rings
(limited types)

\[ R = \langle 1, f \rangle \]
1. \[ C = \langle 1, i \rangle (i^2 = -1) \]
2. \[ D = \langle 1, j \rangle (j^2 = 1) \]
3. \[ E = \langle 1, k \rangle (k^2 = 0) \]

\[ R = \langle g, h \rangle \]
4. \[ F_1 = \langle g, h \rangle (g^2 = h^2 = ...) \]
5. \[ F_2 = \langle g, h \rangle (g^2 = gh = ...) \]
6. \[ F_3 = \langle g, h \rangle (g^2 = gh = ...) \]
7. \[ F_4 = \langle g, h \rangle (g^2 = gh = ...) \]
8. \[ F_5 = \langle g, h \rangle (g^2 = hg = ...) \]
II. Application for Low Altitude Airspace Management
The geo-location identification of UAV is the basis of UAV control.

UAV identification should not only provide powerful means for UAV real-time monitoring, but also realize the maximum utilization of airspace through effective control on the premise of ensuring safety.

Geo-location information is the core component of UAV identification. It is a dynamic identification information, which has a huge amount of data. Its coding, transmission, exchange and processing are relatively complex. It needs to adopt appropriate spatial location framework system standards to achieve high efficiency.
International Developments of UAV Grids

1. Construction of UAV 3D Grid Map in South Korea

South Korea's Ministry of Transport announced in 2016 that it would build a 3D grid map with detailed obstacle technology and information, which can be used for UAV flight test in designated areas. 3D grid map was also built in ningyue county and Gaoxing county for the first time.

2. UAV Airspace Grid Map of US FAA

FAA released the UAV airspace grid map in 2017, drawing the airspace restrictions and altitude restrictions for the use of UAVs in the airport airspace. The number on the grid unit indicates that the distance from the airport is different, and the maximum flight height of the UAV is allowed to be different.
3. Trial Implementation of Grid Airspace Management Technology in Shenzhen

In 2018, Shenzhen launched the pilot work of UAV flight management. Based on the grid based airspace management technology, it has established the control airspace and the flyable airspace for micro and light UAVs, which not only effectively avoid sensitive areas, ensure multi-party security, but also meet the flight needs of UAV users and industry development needs, aiming to standardize civil UAV flight activities in Shenzhen.

4. UAV Operation Airspace Grid Map constructed by Southwest Air Traffic Control Bureau

In 2018, Southwest Air Traffic Control Bureau completed the first phase of UAV operation airspace grid map, after a continuously track and study of the FAA UAS facility map. According to the current laws and regulations on UAV management and use of UAV airspace in China, the research team of Southwest Air Traffic Control Bureau also drew the grid map of UAV operation airspace in the D-class airspace of Chengdu Shuangliu International Airport with reference to the relevant FAA rules, combined with the comprehensive factors such as airspace conditions and flight procedures of Chengdu Shuangliu International Airport.
We drafted "Civil UAV system identification part 10: the 3D space location identification code" under the workgroup of UAV license and UAV identification module of National Information Technology Standardization Technical Committee (TC28 / SC17), which has entered the national standard project approval process.

The IEEE Standard Committee p1939.1 standard for a framework for structural low altitude airspace for unmanned aerial vehicle (UAV) operations standard chaired by Mr. Liao Xiaohan, including the gridding part, is in the charge of Peking University Collaborative Innovation Center for Geospatial Big Data.
The three-dimensional subdivision system is the theoretical basis. Classification of spatial elements is designed and the coding rules are set according to the subdivision system.

According to the coding rules, the spatial elements are coded, indexed and assigned attributes.

According to the element coding and coding index, various applications could be carried out.
Representative Application Scenarios

The traditional path traversal multi-variable conflict calculation is transformed into the grid conflict status query of distributed grid database.

(a) Spatial-temporal subdivision coding model is established based on spatial domain. The model describes the geometric characteristics of orbit, low altitude obstacles or dangerous areas, and uses grid code to identify the grid.

(b) Design database table structure of grid and create grid database.

(c) Establish multi-level grid spatiotemporal index, design query optimization scheme, and check flight conflict detection results from grid database.

Low Altitude Flight Conflict Recognition
UAV route planning is a comprehensive process, which can be divided into two stages: one is environment modeling stage, the other is track search stage. Environmental modeling stage is an important part of route planning. On the basis of the environment model, the reasonable cost function is designed in the stage of track search, and the optimal value of the cost function is obtained by applying the corresponding path planning algorithm.

On the basis of space grid environment modeling, the maximum height, attack angle and turning radius of UAV are organized into grid, and the path planning algorithm could be used to plan the path that meets the requirements.
Advantages of "non-equal size" grids:

1) Design grids based-on longitude-latitude system which can be easily integrated with current GIS and map systems.

2) For most area on earth surface simple square grids can be used.

3) For such simple shape grids, the same shape sub-grids could be used for aggregation and subdivision.

4) Extension to height and time will be hard for equal-size.
Future ISO Plan

Geographic information — Discrete Global Grid Systems Specifications —

Part 1:
Core Reference System and Operations, and Equal Area Earth Reference System

Partie 1:
Système de Référence et Opérations de Base, et Système de Référence Terrestre à Zone Égale

DIS stage
Thank you!